Effect of Head Diameter on Passive and Active Dynamic Hip Dislocation

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Introduction
Recent advances in hard-on-hard bearings and newer generation cross-linked polyethylene liners has renewed the interest in larger head sizes. Increasing head size theoretically increases hip range of motion before impingement and therefore can reduce the potential for hip dislocation. We had previously reported that increasing head-size beyond 32mm head diameter did little to improve hip range of motion because bony impingement became the limiting factor, especially when the components were at or near optimal orientation. However, in addition to impingement and range of motion, hip dislocation is dependent on capsuloligamentous stability. Apart from increasing range of motion, larger heads also increase the distance necessary for the head to translate before dislocating out of the socket and may therefore have an additional benefit even if bony impingement were limiting range of motion. To test this hypothesis we constructed a computer model of dynamic hip dislocation using rigid body mechanics and contact to study the effect of head size on the risk for postoperative dislocation.

Methods
Femoral and acetabular geometry was constructed after segmenting CT scans of hips (N=9) in a commercial software program (MIMICS, Materialise, Belgium). CAD models of total hip arthroplasty components were obtained from Stryker Orthopaedics (Mahwah, NJ) for a current generation hemispherical liner (Trident™). The acetabular shell was assembled with a femoral component with a neck diameter of 12.5mm and neck-stem angle of 132°. The femoral head diameters were tested 28mm, 32mm, and 36mm with liners of corresponding inner diameter. Components were virtually implanted in the 3D CT reconstructed anatomic models using LifeMOD (LifeModeler, San Clemente, CA) and all acetabular cups were placed in 45° abduction and 20° anteverision. Superior and inferior iliofemoral, and ischiofemoral ligaments were modeled to represent the hip capsule. These ligaments were constructed of ellipsoids connected with springs. Spring stiffness was based on previously reported soft tissue material properties. The ellipsoids were used to detect contact between the ligaments and the hip components to simulate capsular wrapping and compute resistance to dislocation. Contact was also simulated between the head and the liner for both designs with a coefficient of friction of 0.09 to represent the behavior of polished metal-on-polyethylene.

Fig 1: Posterior view of the hip model in the position of the intra-operative stability test with the hip in 100° of flexion and 15° of internal rotation.

Rising from a low chair is an activity that increases the risk for posterior dislocation and was simulated by placing the hip in 90° of flexion, 10° of internal rotation, and 10° of adduction. The hip was flexed until impingement and dislocation. A passive intra-operative test used by the surgeons at our institute to assess stability was also simulated. The hip was placed in 100° of flexion and 15° of internal rotation. The hip was then adducted until impingement and dislocation. Peak resisting moment and angle of impingement were measured for the two designs each under the two conditions.

Results
Final impingement before dislocation was at the prosthetic level for 6 out of the 9 subjects (bony impingement occurred in the remaining 3) for the 28mm head size. Increasing the head size to 36mm only reduced the incidence of prosthetic impingement in one subject.

Chair Rise: Increasing head size significantly increased flexion angle and dislocation moment (Repeated Measures ANOVA, p <0.05). Increasing head size also generated a higher moment resisting dislocation (p<0.05).

Intraoperative stability test: The hip adduction angle at impingement was significantly higher in larger heads (p <0.05). Larger heads also generated a higher moment resisting dislocation (p<0.002).

Discussion & Conclusion:
We constructed a computer model of hip dislocation based on rigid body mechanics and contact, incorporating the effect of local bony anatomy and capsular restraints on dynamic posterior dislocation. Head size had a significant effect on maximum flexion angle before impingement and on the peak dislocation moment while rising from a low chair. Greater flexion and higher peak dislocation moment indicate increased hip stability. Thus larger heads appear to significantly reduced the potential risk for posterior dislocation in this high-risk activity.

These results are supported our clinical report of reduced dislocation rates with 32mm and 36mm head sizes compared to 28mm head size.

Surgeons often check the intra-operative stability of the hip with trial components. One such test is measurement of the maximum range of adduction possible with the hip in 100° flexion and 15° of internal rotation. However, the validity of the test and its sensitivity in identifying risk for postoperative dislocation is not known. These results indicate that while the absolute magnitudes of peak dislocation moment during intra-operative stability testing were somewhat different from the postoperative chair rise, the relative differences between the three head sizes were similar. This finding reinforces the validity and clinical relevance of a passive intra-operative test.

While this study incorporated subject-specific bony anatomy and hip ligament insertions, the same material properties were used for all subjects. These material properties were that reported for normal hips. Hip arthroplasty involves capsulotomy and repair which may substantially affect the mechanical behavior and resistance to dislocation. While a higher dislocation moment indicates a greater resistance to dislocation, this moment cannot be greater than the value that corresponds to the ultimate strength of the restraining ligaments. Therefore, there is a limit at which increases in head size will not result in a greater dislocation moment. Finally, increasing head size to correct suboptimal implant position may prevent dislocation but will likely lead to repeated impingement with associated damage and wear.

References